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ABSTRACT

The most important concern in the design, construction and operation of nuclear powerplants is safety. Nuclear power is one of the major contributors to the nation's supply of electricity; therefore, it is important to assure its safe use. Each different type of powerplant has special design features and systems to protect health and safety. One safety concern that is unique to producing electricity at nuclear powerplants is the potential for accidents involving radioactivity. The safety features of a nuclear powerplant are designed to provide maximum safety and to minimize the chance of accidental emission of radiation. This publication reports on the following: (1) safety by design which includes natural safeguards, physical containment barriers, and engineered safety systems; (2) safety through planning of siting, licensing, emergency response, and insurance; (3) Three Mile Island; and (4) safety first. (RT)

Nuclear
Energy

Nuclear Powerplant Safety: DESIGN AND PLANNING

Assistant Secretary for
Nuclear Energy
Office of Support Programs

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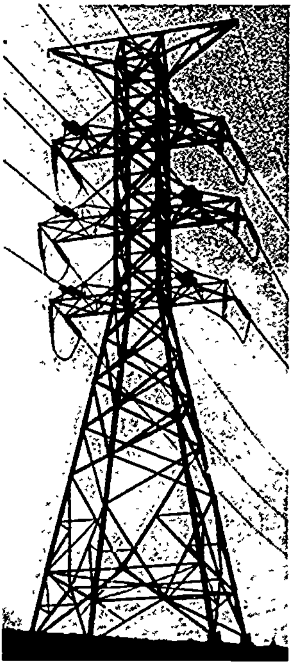
Nuclear Powerplant Safety: Design and Planning

Safety is of utmost importance in the design, construction, and operation of nuclear powerplants. The public has expressed legitimate concern about the adequacy of safety systems and planning at nuclear-powered electrical generating plants. Because nuclear power is now one of the major contributors to the Nation's supply of electricity, it is important that provisions are made to assure its safe use.

Each method of producing electricity has its own set of safety concerns. For this reason, each different type of powerplant—coal, oil, gas, nuclear, hydro—has special design features and systems to protect health and safety. The one safety concern that is unique to producing electricity at nuclear powerplants is the potential for an accident involving radioactivity. This is because radioactive materials are produced in the reactor fuel during the fission process, which is the method of producing heat in a nuclear powerplant.



Nuclear power has become a significant source of electrical energy.

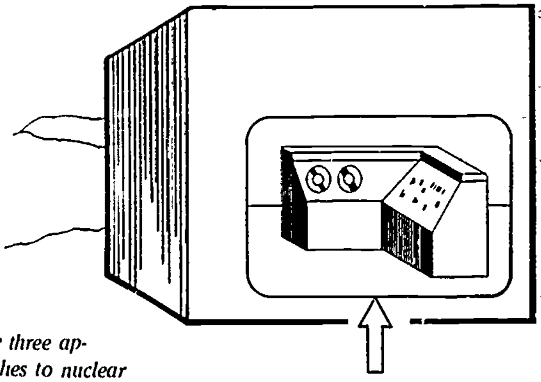
The safety features of a nuclear powerplant are designed to provide maximum safety and reliability and to minimize the chance of an accidental release of radioactivity.

SAFETY BY DESIGN

Nuclear powerplants contain natural safeguards, physical containment barriers, and engineered safety systems that monitor and control reactor operation. These three approaches to design overlap to meet the high standards of safety and to protect the public, the environment, and the facility.

Natural Safeguards

Certain characteristics of nuclear power production act as natural safeguards against accidents. Such "inherent" safety features are actually characteristics of the fuel, the coolant, and the chain reaction process. Nuclear powerplants have been especially designed to take advantage of these natural properties.



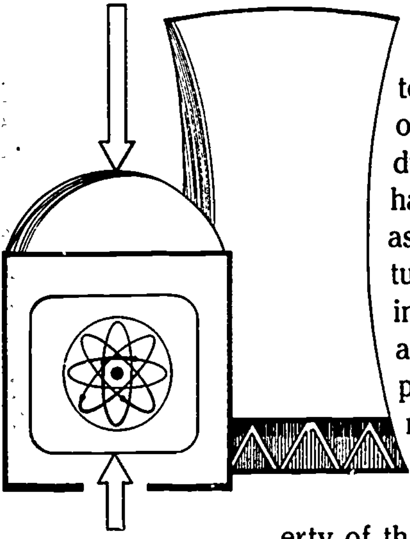
These three approaches to nuclear powerplant design help to provide maximum safety and [illegible]bility.

In a nuclear reactor, heat is produced as atoms of fuel are split in a chain reaction. Although the basic process of nuclear reactors and nuclear weapons is the same, the conditions are very different. A reactor, using fuel that is much less concentrated than that in nuclear weapons, produces heat at a steady, controlled rate. It is impossible for a nuclear powerplant to explode like an atomic bomb.

Another property of the fuel is that as its temperature rises, the chain reaction slows down. This limits heat production through what is known as the Doppler effect.

Water is used as a coolant in most of today's nuclear reactors and is essential for the chain reaction to occur. Water serves two important safety functions. First, it is used to cool the fuel to prevent overheating. Second, it helps to limit the rate of the heat production. This happens because, as the temperature of water increases, its ability to support a chain reaction decreases. This inherent property of the water coolant adds to the ability to control the reactor.

Physical Containment



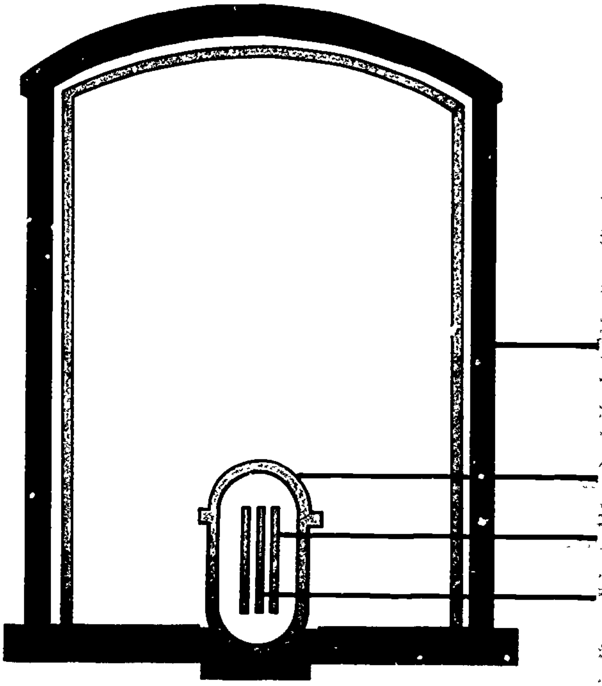
Natural Safeguards

Physical Containment

Radioactive materials are kept, or contained, inside nuclear powerplants by numerous protective barriers. These containment systems are designed to prevent leakage of a harmful amount of radioactivity into the environment should an accident occur.

The first barrier is the nuclear fuel itself. Enriched uranium is formed into cylindrical, ceramic oxide pellets. These pellets will not dissolve or melt, even at temperatures up to 3,000°F. This is far hotter than the operating temperature of the reactor core.

Fuel pellets are stacked in tubes of a strong metal alloy of zirconium that was developed especially for use in nuclear reactors. This metal "cladding" is highly



resistant to damage by radiation. The ends of these tubes are sealed to form airtight fuel pins, which provide the second barrier. The metal gives added protection to the fuel pellets and keeps radioactive gases from being released into the rest of the reactor system. The small amount of radioactive material that might leak through the cladding is collected by filters and absorbers in the coolant system.

Depending upon the reactor design, from 64 to 256 fuel pins are arranged together to form a fuel assembly. Several hundred fuel assemblies are joined together to form the reactor core. The steel pressure vessel surrounding the reactor core is the third protective barrier. A typical vessel weighs more than 500 tons and has a 9-inch-thick wall of carbon steel lined with stainless steel.

containment building

pressure vessel

fuel pins

fuel pellets

Multiple physical barriers minimize the chances of an accidental release of radioactivity into the environment.

From 64 to 256 fuel pins are arranged together to form a fuel assembly.

Surrounding the reactor vessel is the fourth protective barrier—a steel-reinforced concrete building with walls 3 or more feet thick. Government regulations require that this containment building be strong enough to withstand the most severe outside event, such as an earthquake, a violent storm, a flood, or the crash of a large aircraft. From the inside, the reactor containment building is designed to keep radioactivity in, even if human errors and mechanical failures cause a serious accident. All components that could possibly release radioactivity are housed in this ure.

Engineered Safety Systems

Nuclear reactors are designed, built, and operated with multiple safety systems as a backup for equipment failure, human error, and natural disasters. These systems are used to prevent reactor accidents and to minimize the effects if such accidents occur.

The worst accident that could occur in the operation of a nuclear powerplant would be a core meltdown accident. For this to occur, all the cooling water would have to be lost from around the fuel for an extended period, causing temperatures to rise to the point that the fuel pellets and cladding would melt. This might result in a large release of radioactivity into the environment. The chances of such an accident occurring are extremely low because of the numerous safety systems that are activated as soon as the temperature rises above normal levels.

Nuclear powerplants have systems that immediately shut down the reactor when monitoring instruments indicate any problem. Sensitive leak detection equipment provides early warning of any failure in the cooling system. All crucial safety systems have backups that duplicate their jobs. In addition to the primary cooling system, reactors have separate and independent emergency cooling systems that are activated automatically when safety sensors detect a loss of coolant. On-site electrical generators are available to provide emergency power to operate cooling pumps and emergency equipment in the [illegible] of an off-site power failure.

SAFETY THROUGH PLANNING

Extensive planning for safety begins even before a powerplant site is selected. Federal regulations that govern the design, construction, and operation of nuclear powerplants require that, above all, proper attention be given to safety.

Yet no system, however carefully engineered and regulated, can absolutely guarantee that an accident will never occur. The possibility of an emergency always exists and must not be overlooked. Therefore, regulations also exist to protect the public from both harm and financial loss should an accident occur.

The nuclear industry's rigid safety standards are set and strictly regulated by an independent Government agency called the Nuclear Regulatory Commission (NRC). The NRC bears the primary responsibility for regulating the construction and operation of nuclear powerplants.

Siting

Federal regulations require that a number of factors be considered before a powerplant site is selected. These factors include:

- the size of the site
- the stability of the land
- prevailing weather patterns in the area
- the characteristics of water flow in the area
- the characteristics of the earth and rock on the site
- population density around the proposed nt

Following a thorough evaluation of the environmental studies, and after reviewing all factors, NRC experts determine whether or not the proposed site is in accordance with the regulations.

In deciding whether a plant site is suitable, the NRC considers two boundaries that are required around the plant to provide an additional measure of safety. The "exclusion area" is the immediate area around the powerplant over which the utility has complete authority. The "low population zone" surrounds the exclusion area. It is usually a circle extending 2 to 3 miles from the plant. The outer edge of this zone must be a mile or more from the nearest population center.

Licensing

A utility must follow a series of complex licensing procedures before it can build a nuclear powerplant. Two permits must be obtained by the utility—one to build the plant and another to operate it.

To obtain a construction permit, a utility must submit a formal application to the NRC. The application must describe the design and location of the proposed plant and the safety systems to be provided. A review is made of the environmental impact of constructing and operating the plant.

The utility must also prepare safety analysis reports that contain information on the selection of site, choice of materials, design of the equipment, assurance, and accident analysis.

Potential accidents, from minor disturbances to major breakdowns, are studied. The detailed analyses must show that all of the potential accidents can be handled by the emergency systems without jeopardizing public health and safety.

A series of public hearings is required as part of the entire licensing process. These hearings give private citizens, community and special interest groups, and State and local officials an opportunity to express their views about the plant. Interested citizens may appear simply to make statements, or they may formally petition to intervene as full participants in the hearings.

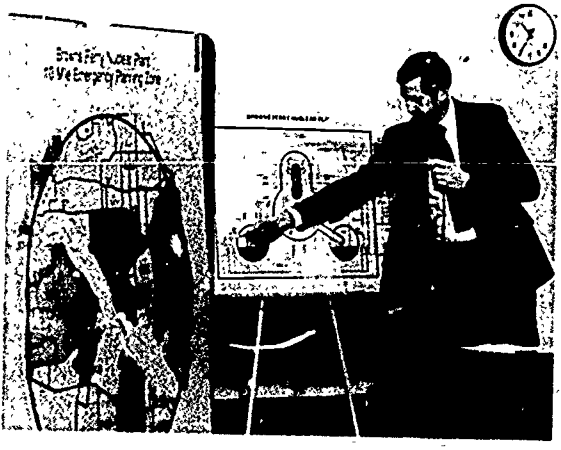
A series of hearings gives the public an opportunity to express their views on proposed nuclear powerplants.

Before a construction permit is issued, the project is evaluated by the Advisory Committee on Reactor Safeguards (ACRS), a panel of experts who work independently of the NRC. The record is reviewed for conformity with the regulations. Based on the results of the public hearings and the ACRS evaluation, the NRC issues or denies a construction permit.

Under current regulations, the entire procedure is essentially repeated to obtain an operating license. If granted a license, a utility must operate the plant in strict accordance with the details of the license. The utility faces severe penalties, including loss of license, if NRC inspections show that the plant is not operated in compliance with Federal regulations.

Emergency Response Planning

Every nuclear powerplant is required by the NRC to plan for potential emergencies that might occur. Utilities are required to develop extensive evacuation plans for the 10 miles surrounding their plants before they may receive an operating license. Together with corresponding State and local governments, utilities must ensure that all residents within this radius are aware of these specific emergency plans.



The NRC requires each utility to develop emergency plans for a 10-mile radius around a nuclear powerplant.

Adequate emergency facilities and equipment must be available for use in the event of an accident. Each utility must provide and maintain equipment to monitor data on radiation levels, weather conditions, and reactor processes.

Provisions are made in advance for direct communication among response organizations, powerplant staff, and the public. Twenty-four-hour direct telephone lines must be installed at each operating plant. These provide immediate notification and continuous communication with appropriate emergency response organizations.

Radiological equipment is used to monitor and assess data in the event of a nuclear powerplant emergency.

Periodic emergency exercises and drills are conducted by utilities and State and local agencies to ensure that all organizations and all personnel know what to do if an actual emergency occurs.

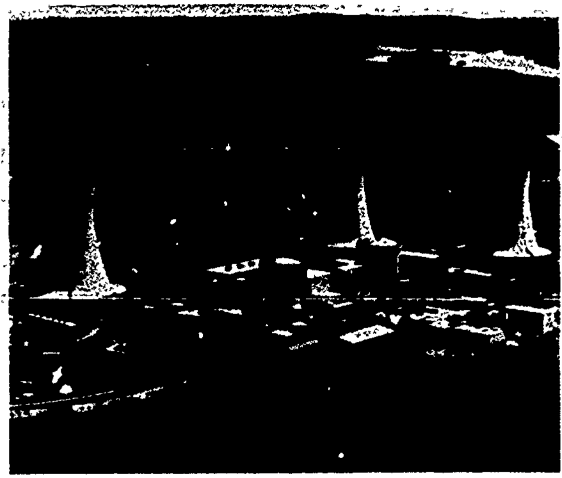
Insurance

All utilities operating nuclear power-plants are required to carry liability insurance to protect the public financially in case of an accident. The Price-Anderson Act, passed by Congress in 1957, requires each nuclear reactor owner to contribute to a liability insurance pool worth more than $500 million.

In the event that an individual's property were ever damaged due to an accident, he could file a claim against the utility operating the nuclear facility, just as he could against a driver who damaged his parked car. The utility operating the nuclear facility is covered for such damage, both by liability insurance from private insurance companies and by Government-backed insurance provided through the Price-Anderson Act.

THREE MILE ISLAND

The Three Mile Island Nuclear Powerplant near Harrisburg, Pennsylvania, experienced a partial loss-of-coolant accident in March 1979, due to human error and mechanical malfunction. Although the reactor's core was damaged during the accident, only a small amount of radioactivity was released into the environment. Government studies following the accident indicate that automatic safety controls would have prevented core damage if emergency systems had not been turned off by plant operators. Though the accident at Three Mile Island is considered the worst in commercial reactor history, the safety systems and barriers worked as they were designed. Neither plant personnel nor members of the public were injured.



Three Mile Island Nuclear Powerplant, Harrisburg, Pennsylvania

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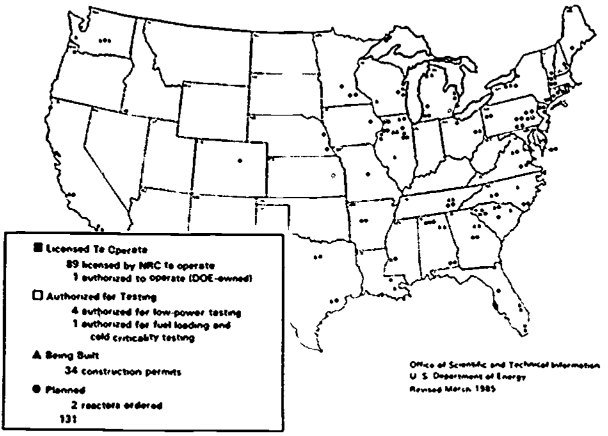
The Three Mile Island accident prompted a thorough re-examination of nuclear powerplant design, safety, and emergency planning. The accident has been studied by numerous groups including the Presidentially appointed Kemeny Commission, the NRC, and Congressional groups.

Based on information gained from the studies of the accident, modifications to plant design have been made to improve powerplant safety. These modifications include:

- laying of direct communication lines between the control room, the NRC, and reactor designers
- placement of more instruments in the control room to give operators information on important conditions at a glance
- changes in control room layout to enable reactor operators to work more efficiently
- establishment of three separate support centers at each facility to report plant status, to coordinate personnel, and to support reactor operators

Three Mile Island also illustrated the need for more clearly defined emergency response plans. Many of the stringent emergency preparedness requirements now in effect were developed after investigations pointed out areas in which improvements were needed. Lessons learned from the Three Mile Island accident are being used to further increase the safety of nuclear energy production.

COMMERCIAL NUCLEAR POWER REACTORS IN THE UNITED STATES



SAFETY FIRST

There are currently about 90 nuclear reactors with operating licenses in the United States. More than 30 reactors have construction permits.

Nuclear powerplants are planned, designed, and constructed to be safe. The safety record for their commercial operation reflects this. Nuclear powerplants have been operating for almost three decades. During this time, a nuclear powerplant-related accident has never caused a death or injury to any member of the public.

No beneficial activity is without risk—including the production of electricity. There are risks involved with nuclear energy, but numerous safety precautions are taken to reduce the chance of accidents. Advance planning for safety and careful design have helped to ensure that this energy resource can continue to provide a reliable contribution to America's energy mix.

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This is one in a series of publications on nuclear energy. For additional information on a specific subject, please write to ENERGY, P.O. BOX 62, OAK RIDGE, TN 37830.